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**MASSACHUSETTS INSTITUTE OF TECHNOLOGY
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Administrative Offices

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June 25, 1991

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Mr. K. D. Sowell
 Grant Negotiator/Administrator
 Mail Code EM25
 George C. Marshall Space Flight Center
 Marshall Space Flight Center, Alabama 35812

**RE: Final Report for NAG8-674 MIT 99567 "Research in Quasi-periodic
 Oscillations and X-Ray Burst Using the EXOSAT Databank"
 PI: Professor Walter H.G. Lewin**

Dear Mr. Sowell:

The Center for Space Research at the Massachusetts Institute of Technology hereby submits two copies of the final report for the above referenced grant.

If you have any further questions of an administrative nature please call me at (617) 253-6103. Questions of a technical nature should be directed to Professor Walter Lewin(617) 253-4282. Thank you for your help.

Sincerely,

Paula M. Suvanto, Administrative Officer

Enclosures

XC: Ms. Donna Havrisik, Mail Code AP326, Marshall Space Flight Center(1)
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(NASA-CR-193346) RESEARCH IN
 QUASI-PERIODIC OSCILLATIONS AND X
 RAY BURST USING THE EXOSAT DATABANK
 Final Report (MIT) 7 p

DSR 99567

Research in Quasi-periodic Oscillations and X-ray Bursts using the EXOSAT Databank

PI: Walter H. G. Lewin

Period: October 1, 1987 to October 1, 1990

During the three years of this program, data from the European X-ray Observatory EXOSAT were analyzed by graduate and undergraduate students at MIT and by our collaborators at the University of Amsterdam. Three undergraduates at MIT (Eugene Magnier, Gregory Black and Lori Lubin) wrote their senior thesis on these data and one student (Jianmin Tan) received his PhD using these data.

Great advances were made in X-ray bursts (thermonuclear flashes on the surface of accreting neutron stars); particularly new light was thrown on the steady nuclear fusion that occurs between the bursts. The possibility of distracting the mass and radii of neutron stars using the bursts that cause photospheric radius expansion was explored in some detail. We concluded that more theoretical work is needed on the understanding of the X-ray spectra before a sufficient accuracy can be obtained to constrain equations of state of neutron star matter.

Our new results on quasi-periodic oscillations (QPO) led ultimately to a new classification by G. Hasinger and M. van der Klis which gave new insights in the mechanisms of the QPOs.

This 3-year program was very successful. It resulted in 29 publications which are listed below; they should speak for themselves.

"Quasi-Periodic Oscillations in the X-Ray Flux of the Rapid Burster (MXB 1730-335)", L. Stella, F. Haberl, W.H.G. Lewin, A. Parmar, J. v. Paradijs, and N.E. White, Ap. J., 324, 379, (1988).

"Time Lags in the Quasi-Periodic Oscillations of the Rapid Burster (MXB 1730-335)", L. Stella, F. Haberl, W.H.G. Lewin, A. Parmar, M. v.d. Klis, and J. van Paradijs. Ap. J. (Lett), 327, L13 (1988).

"Quasi-Periodic Oscillations in the Bright Galactic Bulge X-Ray Source GX 340+0", J. van Paradijs, G. Hasinger, W.H.G. Lewin, M. v.d. Klis, M. Sztajno, N. Schulz, and F. Jansen, Mon. Not. Roy. Astron. Soc., 231, 379, (1988).

"On the Recurrence Behavior of X-Ray Bursts from 4U/MXB 1735-44", J. v. Paradijs, W. Penninx, W.H.G. Lewin, M. Sztajno, and J. Trümper, Astron. & Astroph., 192, 147, (1988).

"On the Relation between X-ray Burst Properties and the Persistent X-ray Luminosity", J. van Paradijs, W. Penninx, and W.H.G. Lewin, Mon. Not. Roy. Astron. Soc., 233, 437 (1988).

"X-ray Bursts - Some Recent Developments", J. van Paradijs, and W.H.G. Lewin, Proceedings of the COSPAR/IAU Symposium "The Physics of Compact Objects, Theory versus Observations", Sofia Bulgaria (eds. L. Filipov and N.E. White), Pergamon Press, Advances in Space Research, 8, #2-3, 461, (1988).

"X-ray Bursts - Some Recent Developments", J. van Paradijs, and W.H.G. Lewin, Memorie della Societa Italiana, 59, No 1-2, p. 213, 1988. Reprinted in "X-Ray Astronomy with EXOSAT", eds. R. Pallavicini and N.E. White, Publisher: EXOSAT Observatory, Noordwijk, The Netherlands.

"A Review of Quasi-Periodic Oscillations in Low-mass X-ray Binaries", W.H.G. Lewin, J. van Paradijs, and M. v.d. Klis, Space Science Reviews, 46, 273 (1988).

"On the Interpretation of Multi-Peak Structure Observed in Some X-Ray Bursts from 4U/MXB 1636-53", M.Y. Fujimoto, M. Sztajno, W.H.G. Lewin, and J. v. Paradijs, *Astron. & Astroph.*, **199**, L9 (1988).

"Search for Quasi-Periodic Oscillations in the X-Ray Flux of 1735-44", W. Penninx, G. Hasinger, W.H.G. Lewin, J. v. Paradijs, M. v.d. Klis, M. Sztajno, and A. Langmeier, submitted to *Mon. Not. Roy. Astr. Soc.*, **238**, 851, (1989).

"X-ray Bursts from 4U 1705-44: Another Case of Burst Properties Dependent on the Strength of the Persistent Emission", M. Gottwald, F. Haberl, A. Langmeier, G. Hasinger, W.H.G. Lewin, and J. van Paradijs, *Ap. J.*, **339**, 1044, (1989).

"Non-Planckian Behaviour of Burst Spectra - Dependence of the Blackbody Radius on the Duration of Bursts", E. Damen, F. Jansen, W. Penninx, T. Oosterbroek, J. v. Paradijs, and W.H.G. Lewin, *Mon. Not. Roy. Astron. Soc.*, **237**, 523, (1989).

"A 4.1 keV Spectral Feature in a Type-1 X-Ray Burst from 1747-21", E. Magnier, W.H.G. Lewin, J. v. Paradijs, J. Tan, W. Penninx, and E. Damen, *Mon. Not. Roy. Astron. Soc.*, **237**, 729, (1989).

"Connections between X-Ray and Optical Variability in the Low-Mass X-Ray Binary 1735-44", R.H.D. Corbet, A.P. Smale, P.A. Charles, W.H.G. Lewin, J.W. Menzies, T. Naylor, J. v. Paradijs, W. Penninx, M. Sztajno, J.R. Thorstensen, and J. Trümper, *Mon. Not. Roy. Astron. Soc.*, **239**, 533, (1989).

"Exosat Observations of 4U 1608-52", W. Penninx, E. Damen, J. Tan, W.H.G. Lewin, and J. van Paradijs, *Astron. & Astroph.*, **208**, 146, (1989).

"Millisecond Radio Pulsars in Globular Clusters", F. Verbunt, W.H.G. Lewin, and J. v. Paradijs, *Mon. Not. Roy. astron. Soc.*, **241**, 51, (1989).

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"Five Lectures on Accretion-driven Stellar X-ray Sources" [1. Galactic Populations of X-Ray Sources, 2. X-Ray Bursts of Type I, 3. Mass-Radius Relation of Neutron Stars, 4. The Rapid Burster (MXB 1730-335), 5. Quasi-Periodic Oscillations], J. van Paradijs, and W.H.G. Lewin. In: "Neutron Stars and their Birth Events", Proceedings of the September 5-17, 1988 Summer School in Erice, Sicily, Italy, ed. W. Kundt, Kluwer, Academic Publ., NATO ASI series, Series C: Mathematical and Physical Sciences, **300**, 219 (1990).

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"Constraints on the Inner Accretion Flow of 4U/MXB 1636-53 from a Comparison of X-ray burst and Persistent Emission", E. Damen, R.A.M.J. Wijers, J.A. v. Paradijs, W. Penninx, T. Oosterbroek, W.H.G. Lewin and F. Jansen, *Astron. Astrophys.*, **233**, 121, (1990).

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"Type II Bursts from the Rapid Burster observed with EXOSAT", J. Tan, W.H.G. Lewin, L.M. Lubin, J. v. Paradijs, W. Penninx, M. v.d. Klis, E. Damen and L. Stella, *Mon. Not. Roy. astron. Soc.*, in press, (1991).

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"EXOSAT Observations of the X-Ray Burst Source 4U 1702-42", T. Oosterbroek, W. Penninx, M. van der Klis, J. van Paradijs, and W.H.G. Lewin, *Astron. Astrophys.*, in press (1991).

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